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Storage Aspects of Continuous Vacuum Foam-Dried Whole Milk

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A few years ago research was initiated in the Engineering and Development Laboratory directed toward developing a commercially feasible process for making beverage-quality dry whole milk of easy dispersibility and adequate shelf-life. The state of the art, at this time, was to dry in air, generally by the spray process, and to forewarm the milk to protect it from oxidation during drying and on storage. Forewarming imparts a cooked flavor and predisposes the product to poor dispersing qualities. The result was a product unacceptable as a beverage. Taking cognizance of this, and the labile nature of milk, a reasonable approach to the problem seemed to be to dry under non-oxidizing conditions and at low temperature, e. g., under vacuum. Furthermore, avoidance of the powdery character typical of spray dried mils would be desirable from the dispersibility standpoint. Thus, studies were undertaken involving concentrating the milk and drying under vacuum in such a way as to form a porous structure. The first significant findings established on a batch scale were that whole milk dried as a foam under vacuum had excellent flavor and unique dispersing properties superior to that dried in other forms (1). It retained, moreover, its good dispersing properties during prolonged storage (2). The principles developed on a batch scale have been applied successfully on a continuous basis (3, 4,). This paper reports on some storage aspects of continuous vacuum foam-dried whole milk made, handled, and packaged with virtually no contact with oxygen.

EXPERIMENTAL PROCEDURE

Dry whole milks used in this study were made by the continuous vacuum foam-drying process. The integrated pilot plant employed is shown schematically in Figure 1. Whole milk adjusted to 3.1% butterfat (26% dry basis) is flash-pasteurized at 162° F for 16½ seconds and homogenized. This is concentrated in an agitated, falling-film vacuum evaporator of the Luwa * type from 12% total solids to an average 45%. The concentrate is homogenized at 3,000—500 psi at 135° F to assure fat particle size reduction to 2 μ or less. Nitrogen gas is metered into the concentrate stream and a scraped-surface heat exchanger then

* Reference to certain products or companies does not imply an endorsement by the Department over others not mentioned.

simultaneously chills the concentrate quickly to 35° F and disperses the gas. Finally, within a drying chamber maintained at about 18 mm Hg absolute, the foamed concentrate is further expanded and applied to and dried on a continuous solid belt.

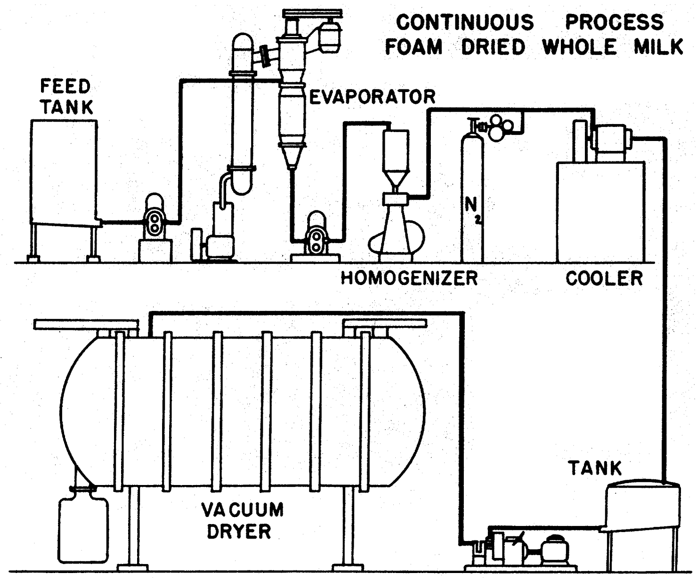

Fig. 1: *Schematic Diagram of the Continuous Vacuum Process for Foam-Dried Whole Milk.*

Figure 2 is a photograph of the continuous vacuum dehydrator used in these studies. Product is collected alternately in the two receivers which are at the same pressure as the drying chamber. When a receiver is full, it is isolated from the drying chamber and the vacuum in the receiver brought up to atmospheric pressure with nitrogen gas. Up to this stage, it is apparent that the milk has been protected from the deteriorative effects of O_2. On a factory scale, this protection can easily be maintained by providing enclosed and N_2-purged transporting and packaging equipment from the receivers. This was simulated on a pilot plant scale by use of the controlled atmosphere cabinet shown in Figure 3. The cabinet is equipped with a product screening device and facilities for filling and sealing cans in a nitrogen atmosphere. The small portion of dried foam that cannot pass through the 20-mesh screen is wiped through by means of a rotating blade. The product is transferred from the receiver into the cabinet by means of special containers, one of which is shown attached to the top of the cabinet. The container previously had been filled with product by using it as a removable inner receiver during dryer operation. In this way vacuum foam-dried milks may be packaged with $< 0.001\%$ O_2 by volume (limit of detectability by the A. O. Beckman E2 O_2 analyzer).

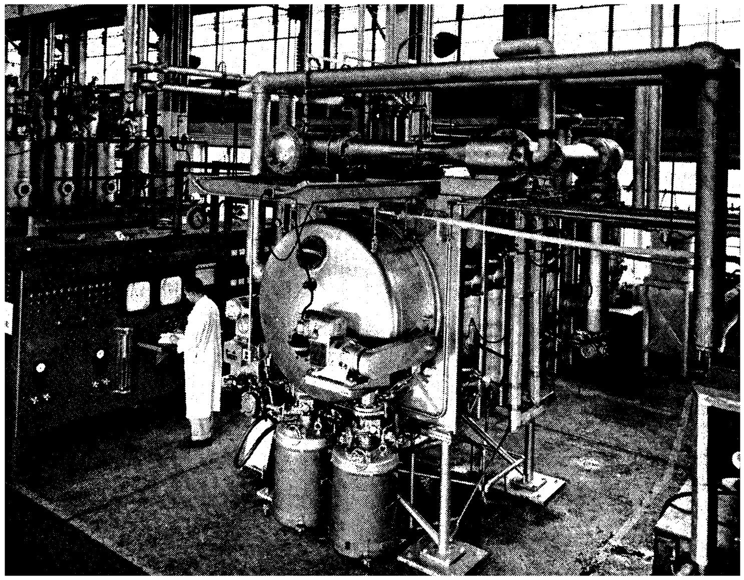

Fig. 2: *Pilot-Plant Scale Continuous Vacuum Dehydrator.*

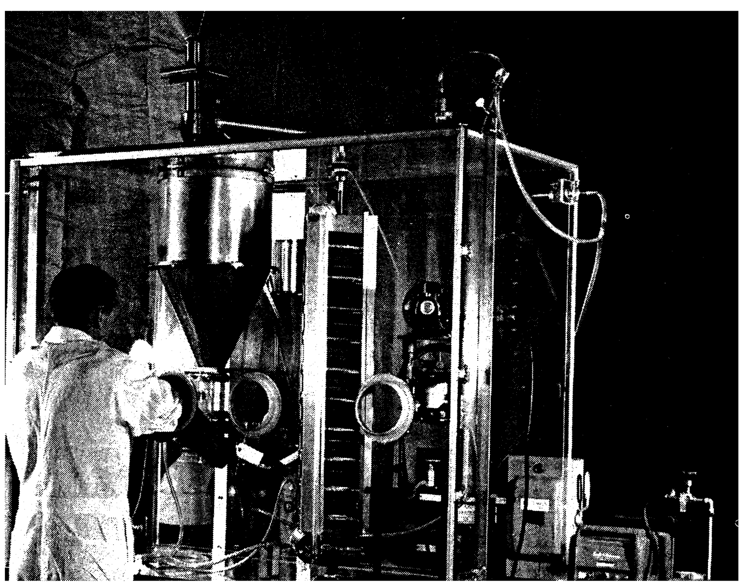

Fig. 3: *Controlled Atmosphere Cabinet for Gas-Packing Dry Whole Milk.*

Storage tests were conducted on ten lots of product prepared and packaged as outlined above. The products were stored at room temperature (73° F) and under ordinary refrigeration (40° F). They were evaluated initially and after 1, 2, 3, 4, 6, 8, and 10 weeks. Thereafter, until termination of the test, they were evaluated at approximately monthly intervals.

Oxygen content of all cans was tested to detect leaks. Only the product in those cans which showed no change of O_2 level were evaluated further.

Flavor evaluation was made by a scoring test similar to the one adopted by the American Dairy Science Association (5) except that a score lower than 20 was not permitted. Ten to fifteen judges commonly were employed for each test. They had been screened on the basis of their taste acuity and trained to distinguish among five off-flavors, viz., cooked, oxidized, stale, lactone (coconut), and rancid (Butyric). Coded samples at 68° F were submitted to the judges who assigned scores based on the intensity and type of off-flavor. The off-flavors found were not limited to those previously mentioned. The reported flavor score is the arithmetical average of the panel's scores for the particular sample. Typically, the expert panel rates a Grade A, fresh, pasteurized market milk at about 39.5. A variety of evidence indicates that a score of 35 by this panel corresponds to the borderline of acceptability for a beverage milk. Corroborative tests were conducted on the same milks by the Rank Paired Comparison test (6, 7) using a somewhat larger panel with milk served at the drinking temperature of about 45° F.

The colorimetric (iodometric) procedure of Swoboda and Lea (8) modified by DellaMonica et al. (9) was used to measure peroxide values. These were calculated from the determined iodine concentration and are expressed as meq. oxygen per kilo of free fat. Four analyses were run, a sample in triplicate plus a reagent blank.

Moisture contents were determined by the use of the conventional toluene distillation technique.

The concentration of 5-hydroxymethylfurfural (HMF) was measured by the method of Keeney and Bassette (10) as modified by Craig et al. (7).

RESULTS AND DISCUSSION

Products were tested initially to assure relative uniformity of the material to be stored by standards previously developed. Initial HMF levels ranged from 0 to 1.2 μ M/l, which can be considered a very low heat dry milk and predisposed to superior storage characteristics (7). Previous work (11) showed a marked influence on storage behavior by moisture when oxygen is present even in small amounts (0.5% by volume). In that work, greater stability was noted at moistures higher than 2.8% wet basis. In the present (very low oxygen) experimental products, moisture levels ranged from 2.8 to 4.1%. Data analysis revealed no effect of moisture on storage quality.

Figure 4 depicts flavor scores for eight dry milks stored at 40° F. After a relatively small drop in flavor in the first 3—4 weeks, the flavor remains essentially stable at a palatable level for upwards of 9 months. Figure 5 depicts flavor scores for

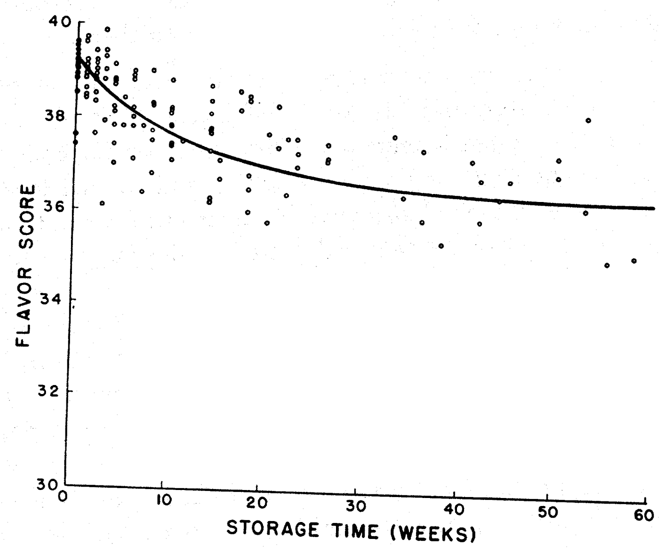

Fig. 4: *Flavor Scores versus Storage Time at 40° F for Continuous Vacuum Foam-Dried Whole Milk.*

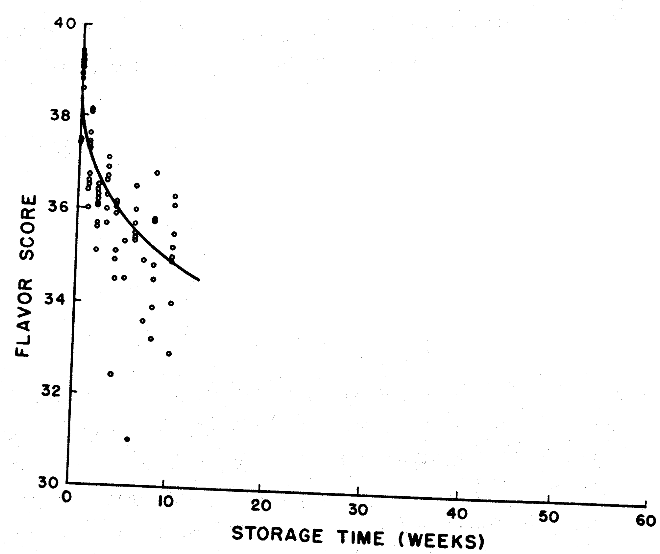

Fig. 5: *Flavor Scores versus Storage Time at 73° F for Continuous Vacuum Foam-Dried Whole Milk.*

samples of the same eight dry milks stored at 73° F. Results of the rank paired comparison tests run concurrently confirm the relative flavor scores.

In the scoring test, each judge specified the off-flavors, if any, considered in assigning a score. Hence, the number of judges reporting a given off-flavor gives a rough measure of the intensity of that off-flavor and the likelihood of its existence. It should be borne in mind that more than one off-flavor may be reported by a judge on a particular sample. Figure 6 illustrates the percentage of judges making "oxidized" comments. Each value is the average for six 73° F storage series. Curve A represents the continuous process material, whereas curve B represents *batch* vacuum foam-dried powders (7). The latter product had some inadvertent exposure to O_2 during processing, was packed in 0.2 to 0.5% O_2 and also was stored at 73° F. Obviously, the oxidative changes have been suppressed greatly in the product of the continuous process.

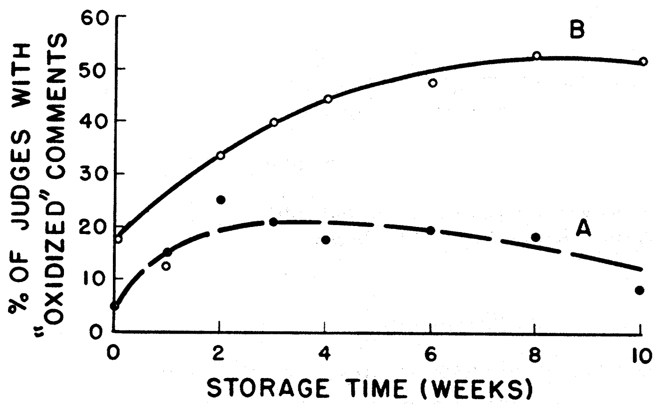

Fig. 6: *Incidence of "Oxidized" Comments as a Function of Storage Time at 73° F.*
A. Continuous Vacuum Foam-Dried Whole Milks.
B. Batch Vacuum Foam-Dried Whole Milks.

Figure 7 represents a further demonstration of the suppression of oxidative effects during storage of the product of the continuous process. Curve B represents peroxide values of the *batch* product previously discussed (7) and curve A those of six continuous process products stored at 73° F. It should be noted that curve B exhibits the "early peak" typical of dry whole milk that has had some contact with oxygen (12). Curve A not only shows a low initial level of peroxide values but also a low rate of change and an apparent complete suppression of the peak.

Thus, since oxidation has been suppressed in the product of the continuous process, as evidenced by organoleptic and chemical means, other changes predominate at 73° F. These may be the formation of "lactone" or "stale" off-flavors. Each of these comments was made by 30—40% of the judges at 3 weeks storage and beyond.

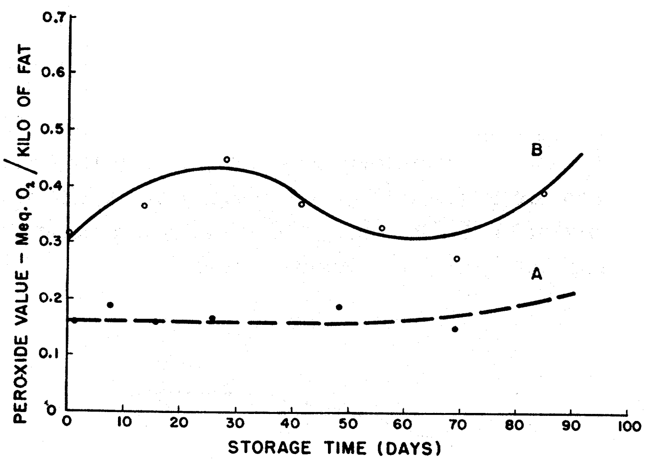

Fig. 7: *Peroxide Values as a Function of Storage Time at 73° F.*
A. Continuous Vacuum Foam-Dried Whole Milks.
B. Batch Vacuum Foam-Dried Whole Milks.

CONCLUSION

An apparent potential of continuous vacuum drying of whole milk was that the near absence of O_2 exposure might eliminate oxidation as a major off-flavor problem. Experimental evidence presented here supports this assumption. Under pilot plant conditions, the simulation of an oxygen-free process has been successful. At 40° F, the product exhibits good keeping properties to 9 months and beyond. For some markets, this has commercial potential. Other deteriorative reactions make storage at room temperature questionable for commercial distribution at this time. It should be noted that little is known about the consumer tolerance of the remaining off-flavors. While all the problems of room temperature storage have not been eliminated, it is felt that a continuous vacuum process will form the basis for a successful solution to the room temperature storage problem.

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